Indicator: Coastal Water Quality Index (332)

Water quality is a critical aspect of coastal aquatic ecosystems, and four interlinked components are especially critical: nutrients (nitrogen and phosphorus), chlorophyll, dissolved oxygen, and water clarity. Nitrogen is understood to be the most important limiting nutrient driving large increases of microscopic phytoplankton in estuaries called "algal blooms," but phosphorus can become limiting in coastal systems if available nitrogen is abundant (EPA, 2003). Nitrogen and phosphorus can come from point sources, such as wastewater treatment plants and industrial effluents, and non-point sources, such as runoff from farms, over-fertilized lawns, leaking septic systems, and atmospheric deposition. Chlorophyll is a measure of the actual abundance of microscopic algae that constitute algal blooms. In addition to nutrients, chlorophyll levels also are affected by declines in filtering organisms like clams, mussels, or oysters. High concentrations of chlorophyll *a* indicate overproduction of algae, which can cause noxious odors, decreased clarity, and low dissolved oxygen. Reduced water clarity (usually measured as the amount and type of light penetrating water to a depth of one meter) can impair normal algae and other submerged vegetation growth. Reduced water clarity can be caused by algal blooms and by storm-related events that cause erosion or mixing from the sediments. Low dissolved oxygen levels caused by algal blooms or the decay of organic matter from the watershed are stressful to estuarine organisms and often lead to algal scums, fish kills, and noxious odors (EPA, 2004).

This indicator, developed as part of EPA's Coastal Condition Report, is based on an index constructed from probabilistic survey data on dissolved oxygen (DO), nitrogen, phosphorus, chlorophyll *a*, and water clarity (EPA, 2004). The survey was designed to be representative of all estuarine waters of the conterminous 48 states and Puerto Rico. The Great lakes indicator is based on available non-probabilistic data. Reference conditions were established for each region for nutrients, water clarity, and chlorophyll a. A national reference condition of 2 mG/L was used for dissolved oxygen, because this measure does not tend to vary by region (Diaz and Rosenberg, 1995; EPA, 2000). Assignments of classifications to individual sits varies by region and is described in detail, along with the regional reference conditions, in EPA (2004, pp 19-20).

The five "sub-indicators" are combined into a single index of water quality. For each site, the indicator is rated high if none of the five components of the index are rated low, and nor more than one is rated moderate. It is rated low if more than two components are rated low. All other sites are rated moderate. If two components of the indicator were missing, and the available indicators did not suggest a moderate or low rating, the site was rated missing. Data from the individual sites then were expanded from the probability sample to provide unbiased estimates of the sub-indicator for each region and for the entire nation.

Regions were rated high if less than 10% of coastal waters were rated low, and less than 50% of coastal waters were in combined low and moderate condition; moderate if 10% to 20% of coastal waters were in low condition, or more than 50% of coastal waters were in combined moderate to low condition; and low if more than 20% of coastal waters were in low condition.

What the Data Show

Data from the National Coastal Assessment indicate that the overall condition of the nation's estuaries as measured by the water quality index is moderate (Figure 332-1). EPA Region 1 was rated high, Region 3 was rated low, and all other Regions and the Great Lakes were rated moderate.

Based on surface area, 11% of the nation's estuaries exhibit low water quality condition scores, 40% exhibit high scores, and 49% is exhibit moderate water quality scores. Only EPA Region 3 had low

ratings for more than 15% of the estuarine area. More than 1/3 of the estuarine area in most EPA Regions was rated high, with Region 1 having 71% of the area rated high.

Based on the individual components of the water quality index, most of the nation's coastal area fell below the corresponding regional reference conditions, ranging from 51% for chlorophyll a to 82% for nitrogen concentrations (Figure 332-2). Areas exceeding reference conditions were generally below 10%, except for water clarity, which exceeded regional reference conditions in 25% of estuaries. These percentages do not include the Great Lakes or the hypoxic zone in offshore Gulf Coast waters (see indicator Areal Extent of Hypoxia in the Gulf of Mexico).

Indicator Limitations

- The coastal areas of Alaska and Hawaii have been sampled, but not yet assessed. Data are also not available for the U.S. Virgin Islands, and the Pacific territories.
- Trend data are not yet available for this indicator.
- The National Coastal Assessment surveys measure dissolved oxygen conditions only in estuarine waters and do not include observations of dissolved oxygen concentrations in offshore coastal shelf waters; such as the hypoxia zone in Gulf of Mexico shelf waters.
- The water quality index used in this report is intended to characterize the typical distribution of water quality conditions in coastal waters. It does not consistently identify the "worst-case" condition for sites experiencing occasional or infrequent hypoxia, nutrient enrichment, or decreased water clarity.

Data Sources

The data source for this indicator is the National Coastal Condition Report II, U.S. Environmental Protection Agency, 2004.
http://www.epa.gov/owow/oceans/nccr/2005/downloads.html

References:

Diaz, R.J. and R. Rosenberg. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioral responses of benthic macrofauna. *Oceanography and Marine Biology Annual Review 33:245-303.*

U.S. Environmental Protection Agency. 2000. Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras. EPA 822-R-00-12. Office of Water/Office of Science and Technology and Office of Research and Development/National Health and Environmental Effects Research Laboratory. November 2000.

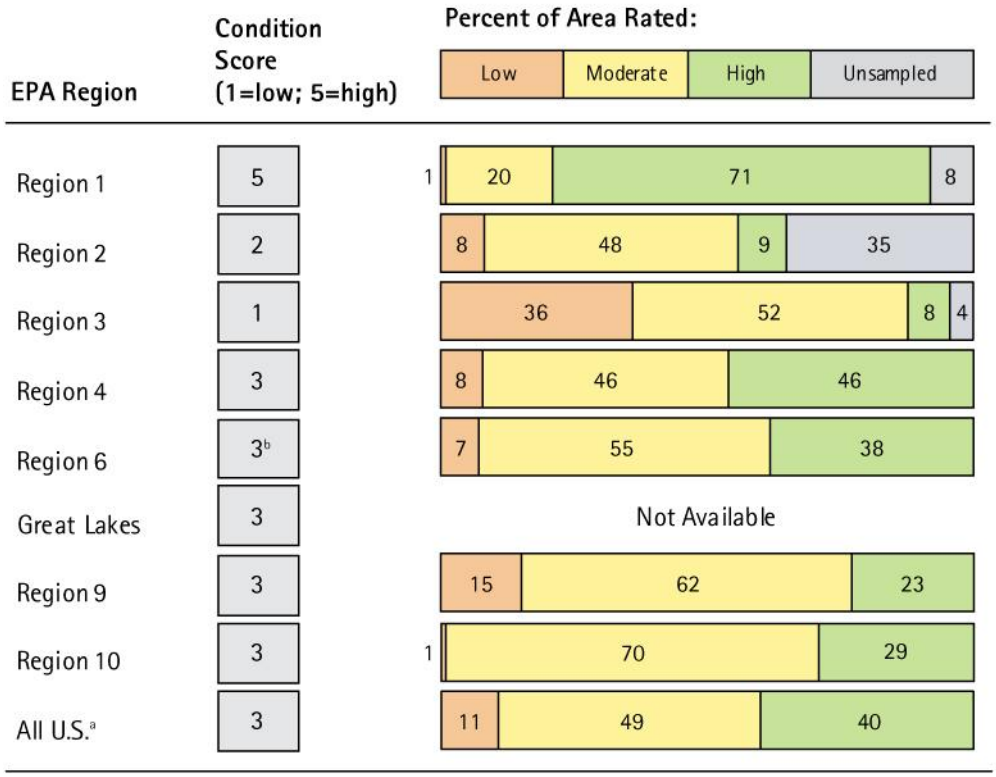
U.S. Environmental Protection Agency. 2003. Mid-Atlantic Integrated Assessment, MAIA – Estuaries 1997-98, Summary Report, EPA 620-R-02-003. Narragansett, RI: U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, May 2003.

EPA. 2004. National Coastal Condition Report II, EPA-620/R-03/002. U.S. Environmental Protection Agency, Washington, DC.

Schindler, D.W. 1977. Evolution of phosphorus limitation in lakes. Science 179:260-262.

Graphics

Figure 332-1: Overall Summary of Condition Based on the Water Quality Index



Source: National Coastal Condition Report II, US EPA, 2004.

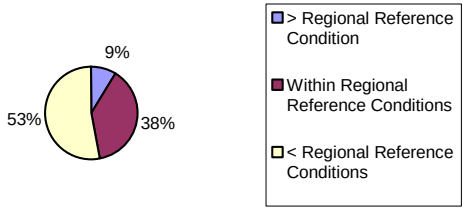
Notes: [a] The national score is based on an aerially weighted mean of the regional scores.

[b] This rating does not include the impact of the hypoxic zone in offshore Gulf Coast waters.

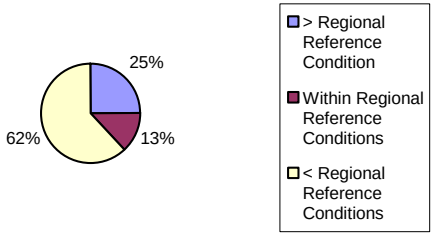
Figure 332-2. Coastal Water Quality, 1997-2000:
Percentage of Estuarine Area (48 Conterminous U.S. States and Puerto Rico)

Dissolved Oxygen Conditions

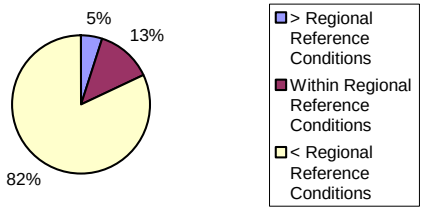
Phosphorus Conditions



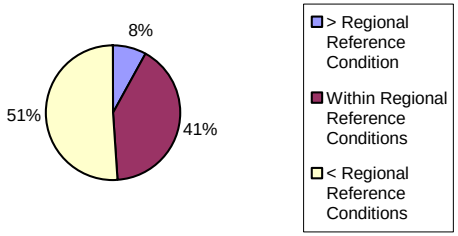
Water Clarity Conditions



Nitrogen Conditions



Chlorophyll a Conditions



Source: EPA, Office of Research and Development and Office of Water. National Coastal Condition Report II. 2004.

R.O.E. Indicator QA/QC

Data Set Name: COASTAL WATER QUALITY INDEX
Indicator Number: 332 (89145)
Data Set Source: EPA/EMAP/NCA
Data Collection Date: 1999-2000
Data Collection Frequency: annually
Data Set Description: The water quality index is intended to characterize acutely degraded water quality conditions. The index is made up of five indicators: nitrogen, phosphorus, chlorophyll a, water clarity, and dissolved oxygen.
Primary ROE Question: What are the trends in extent and condition of coastal waters

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Methods described for this survey represent a combination of standard, scientifically accepted sampling and analytical methodologies. They are described in ; US EPA 2001. National Coastal Assessment: Field Operations Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA 620/R-01/003. pp72. U.S. EPA. 1995. Environmental Monitoring and Assessment Program (EMAP): Laboratory Methods Manual-Estuaries, Volume 1: Biological and Physical Analyses. U.S. Environmental Protection Agency, Office of Research and Development , Narragansett, RI. EPA/620/R-95/008. http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

There is an entire portion of the EMAP website dedicated to principles and implementation of the NCA monitoring design and analysis. http://www.epa.gov/nheerl/arm/index.htm Diaz-Ramos, S., Stevens, D.L., Jr and Olsen, A.R. (1996) EMAP Statistical Methods Manual. Rep. EPA/620/R-96/002, U.S. Environmental Protection Agency, Office of Research and Development, NHEERL-WED, Corvallis, Oregon. Olsen, A.R., Stevens, D.L., Jr. and White, D. (1998) Application of global grids in environmental sampling. Computing Science and Statistics, 30, 279-84. Stevens, D.L., Jr. (1997) Variable density grid-based sampling designs for continuous spatial populations. Environmetrics, 8, 167-95. Stevens, D.L., Jr. and Olsen, A.R. (1999) Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics, 4, 415-28. Stevens, D.L., Jr. and Urquhart, N.S. (1999) Response designs and support regions in sampling continuous domains. Environmetrics, 11, 13-41. Stevens, D. L., Jr. and Olsen, A. R. Variance Estimation for Spatially Balanced Samples of Environmental Resources. Environmetrics 14:593-610. Stevens, D. L., Jr. and A. R. Olsen (2004). "Spatially-balanced sampling of natural resources." Journal of American Statistical Association 99(465): 262-278.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

These measurements were combined into a water quality index because they represent what are considered to be the major components of water quality in estuaries. This was based on a concensus of scientific opinion on the topic.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

Sampling for the indicator presents available information on a national scale for the conterminous 48 states and Puerto Rico. There are 50 sites sampled each year for each of the states or territory. Data collection began in 1999 and is ongoing in 2004.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

Sensitive populations or ecosystems are represented to a limited extent. The monitoring design at the scale presented is to characterize condition on a regional scale, not specific areas.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

Threshold values for water quality indicator components are based on existing criteria, guidelines, or the interpretation of scientific literature. Some of these values were regionally specific, and therefore could not be applied across all geographic areas. Though, each geographic component had identical measurements.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

U.S. EPA. 1995. Environmental Monitoring and Assessment Program (EMAP): Laboratory Methods Manual-Estuaries, Volume 1: Biological and Physical Analyses. U.S. Environmental Protection Agency, Office of Research and Development, Narragansett, RI. EPA/620/R-95/008. U.S. EPA. 2001. Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA/620/R-01/002. U.S. EPA. 2001. National Coastal Assessment Field Operations Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA/620/R-01/003.
http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

http://www.epa.gov/emap/nca/html/data/index.html Stephen Hale, U.S. EPA, Atlantic Ecology Division, (401) 782-3048

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes, Using the documentation provided for the design can be reproduced by a competent statistician. All of the field sampling and analytical methods are also well documented.

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

U.S. EPA. 2001. Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan. . U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA/620/R-01/002 Hale, S., J. Rosen, D. Scott, J. Paul, and M. Hughes. 1999. EMAP Information Management Plan: 1998-2001. U.S. Environmental Protection Agency, Office of Research and Development , Narragansett, RI. http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Not Applicable

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes, measurements of uncertainty are provided with each indicator. http://www.epa.gov/nheerl/arm/index.htm

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Inconsistency in application of the design, sample collection, or sample analysis. These are controlled through standardization of methodologies, publication of operational manuals, and training of personnel involved. It is monitored through quality assurance requirements and audits.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

In the original data set there was an inconsistency in measurements taken for water clarity. Secchi disk depths for all areas and light energy values for some. In order to calculate our water clarity indice, light energy values were required for all sites. A model was developed to predict the light energy penetration using the secchi disk depths so that the indice could be calculated. This paper had been submitted for internal EPA review.